THE PRODUCTION OF TEXTILE MACHINERY.

Paper presented to the Institution, Manchester Section, by H. G. King, M.I.P.E., Section President.

BEFORE dealing with the changes which have taken place in the manufacture of textile machinery, it is necessary to review the trade conditions over a period. Great Britain exported an average of 160,000 tons per annum over the five pre-war years. During the five years just ended exports have dropped to about 60,000 tons—that is to two-fifths. Even this does not represent a true figure of the shrinkage which has taken place, as the home trade—for which, unfortunately, there are no official figures—indicates an even greater proportional drop in production.

The Ministry of Labour figures for the textile machinery industry show that there were employed in 1921, 73,841 males and 5,902 females ; and in 1931, 55,416 males and 4,646 females, that is, a reduction of almost 20,000 in the ten years ended 1931.

The reason for this enormous drop in output and personnel is not far to seek. Apart from the trade depression which all exporting trades have suffered for five or more years, the textile trade was very largely a monopoly trade of this country prior to the war. The bulk of our exports of machinery were to the Far East—Japan chiefly—and, nearer home, Russia represented an enormous market. In 1929, Russia took 8,000 tons of textile machinery, but in 1934 the total was only 129 tons. Over the same period, exports to Japan have fallen from almost 14,000 tons to 1,500 tons last year. These countries now manufacture their own machinery—Japan particularly being a formidable competitor, and, whilst fresh markets are being developed, such as Persia, Egypt, and South America, these markets are divided amongst several exporting nations.

We in this country were therefore faced with a manufacturing capacity many times too great for immediate or future demands and the first problem was one of concentration.

Until the end of the boom period, textile machinery was produced on quantity production lines. Each type of machine was built throughout in a separate department or sectional works. Even quite minor parts were manufactured within that department and, with the exception of the pattern shop, foundry, forge, etc., the departments were self-contained. Each department was in the

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charge of a manager who often evolved the design, supervised the detail manufacture, the progressing, ordering of materials and final erection, and was often in direct touch with the client.

Such conditions lent themselves to cheap and almost ideal quantity production methods and created a demand for the simplest form of single purpose machine tools and for a class of labour which could be drawn from the immediate vicinity of the factory, regardless of training. Boys entered the trade at ages from eight to fourteen years and worked, in some cases, upon no more than two or three operations throughout their lives. In time, such labour became highly skilled, and these men to-day are machines themselves which the modern multi-purpose machine tool is hard put to to beat on a time-output basis. Only five years ago, large numbers of hand turners were still to be seen in all our large textile machine shops.

What is the position to-day? With the establishment of textile engineering factories all over the world, Britain's export trade has almost ceased, with the result that quantity production methods are no longer of use. In consequence, large numbers of such skilled one-operation men and employees of the type mentioned have lost their employment and their means of livelihood is gone.

The effect on standardisation is easily followed. With the growth of exporting nations, sources of supply of raw materials, such as iron and steel and cotton, have been sought within or near to the manufacturing country and cotton growing fields have passed from U.S.A. to Egypt, India, South America, Africa, and China. The varieties of cotton are legion, and the textile engineering trade has to manufacture machines capable of dealing with greatly extended varieties and blendings of raw materials. Thus, far from extending standardisation, we are passing away from it. The demand to-day is for small quantities of machinery having variable characteristics. This, then, briefly, is the position of the textile engineers during the last ten years or so. Many have been unable to survive, others have amalgamated to avoid internal competition, and it is obvious that such conditions are likely to remain for some years.

About five years ago, six of the largest manufacturers in this country adopted the policy of amalgamation and concentration of their manufactures at a limited number of works, together with a complete reorganisation of their manufacturing methods and works. In the first place it was decided to revert to the system of grouped process manufacture; shops were set aside for turning, milling, planing, drilling, etc. The particular firm with which I am associated was established in 1822 and many of the shops were erected well over 100 years ago. Development has taken place piecemeal and is further complicated by the works being on the side of a hill with the foundry at the bottom. Reorganisation was, therefore, no mean task.

Some Manufacturing Details.

The process of converting the cotton into thread consists primarily of drawing and twisting the fibres until they finally become a long unending cotton thread. Before the detailed manufacture of some of the parts is given, a brief description of a typical cotton machine is necessary. One of the most modern machines employed is the ring spinning frame. Almost all the framework used in this and other textile machinery is of cast iron of comparatively thin sections bolted together. The spinning operation depends upon three main parts: (1) The spindle; (2) the spinning ring; (3) the rollers. The first two are mainly concerned with twisting the yarn, the third with the drafting.

Manufacture of the Rails.

The rails which hold the spindles are of cast iron, having a composition of :—

Total carbon	3.25 to 3.45%.
Silicon	2.00 to 2.50%.
Sulphur	0.08 to 0.10%.
Phosphorus	0.95 to 1.10%.
Manganese	0.50 to 0.75%.

Deflection Test.

Bar	1 in. dia.
Breaking load	1,918 lb.
Deflection	0.11 in.
Modulus of Rupture	24.93 tons.

12.7 tons tensile on .564 dia. test bar.

The pattern is usually of metal and mounted upon a plain turnover moulding machine. The mould is rammed by hand but is drawn and turned over by means of a hydraulic crane which runs the full length of the shop. A production of 33 rails per day can be produced by four men. The moulders mould continuously, a separate casting gang and knocking out gang being employed. There are, of course, still many items of textile machines which are produced upon quantity production lines and the subsequent machining of these rails is catered for in a specialised machine shop adjacent to the foundry and on the same floor level. The first five operations are planning operations done upon high speed electric controlled planers using tungsten carbide tools.

Manufacture of Top and Bottom Rollers.

The object of these rollers is for the purpose of attenuating the yarn or fibres. The rollers revolve at different speeds. There are in the modern frame four lines of bottom or fluted rollers revolving

at speeds of from 12 to 180 revs., the front line running fastest. Mounted loosely in bearings over the top of each line of rollers are plain weighted rollers—the object of which is to press the yarn closely into contact with the bottom roller. It will be readily understood that by their differential speed action, these rollers draw out the fibre and attenuate the thread.

The bottom rollers are of mild steel and are fluted to give a grip on the cotton fibre. The rollers are often case-hardened and must be dead smooth and perfectly straight from end to end of a frame. An average frame has 400 spindles and may be 40 to 45 ft. long from end to end. On such a frame there will be 200 rollers. The rollers are coupled together by spigot and socket joints, using four start threads, concentricity of joint being assured by ground collars and bores.

Spinning Rings.

These are produced from medium carbon steel, case-hardened. The forging of the ring is of particular interest, and much thought and research has been expended upon it. The usual method of forging consists of upsetting a steel bar in the horizontal forging machine. There is little waste produced by this method. Actually, only about 8% of the length of the bar is waste. When it is realised that the finished ring has to be almost frictionless and resist the wear of a steel traveller—which is a "C" shaped clip through which the yarn passes—travelling at anything up to 12,000 r.p.m. at a velocity of 40 m.p.h. continuously without any means of lubrication, it will be apparent that such rings must be absolutely accurate and made to extremely fine limits.

In a ring forged by the upset method, the fibre of the material is crushed and lies irregularly over the wearing surface. It is extremely interesting to learn that the initial upset of the bar in immediate contact with the ram of the machine remains on the bar throughout its length, that is to say, the flow of metal to make each successive upset takes place from a portion of the heated bar approximately $^1/_{32}$ in. behind its face. To overcome the distortion of the fibre so produced a method of rolling rings has been evolved.

Limits.

Limits of one-quarter of a thousandth part of an inch are met with in textile machinery and the allowable tolerance on parts unlimited is normally within + and — 6/1000 in. to ensure interchangeability. This figure incidentally applies to all machine parts of textile machinery, even the cast iron framing.

Spindles.

The spindle imparts twist and thereby adds strength to the yarn. The design of the spindle varies according to the material with which it has to deal. In principle, its design has varied little for almost a century. It consists of a cast iron footstep bearing supporting the steel spindle, together with a small plain surface to resist the pull of the driving band. On the steel spindle is mounted a warve or small pulley. The spindle speed to-day reaches 12,000 revs. per minute.

The spindle blade is made from specially cast steel containing 1 to 1.1% carbon and is heat treated after forging and rough grinding. The forging of the blade is done on a Ryder type hammer, and it is interesting to note that they are forged to allowance 15/1000 in. for rough and finish grind to size. It is also important that the spindles are set dead straight in the black, also intermediate and final stages after finish grinding.

The most important feature of a ring spindle is that it should be perfectly balanced so that it will run at all speeds up to 12,000 revs. without any trace of vibration whatever, thus ensuring smooth and even yarn.

The operation of heat treatment is first to heat the spindle in a salt bath to 780°C. for a period of five to seven minutes according to size and diameter, then cool out in water, re-heat in tempering bath to 325°C. for a period of seven minutes and quench in tepid water. After heat treatment, finish grinding and final setting ; these spindles will stand a deflection test with 70 to 80 lb. pull without taking any permanent set. This ensures a long life of spindle and prevents any likelihood of vibration being set up under working conditions, causing bad yarn and loss of production.

The sleeves are made of cast iron and it is important that they be made of close grained homogeneous metal, as any variation or porosity would affect the balance of the spindle after the sleeve had been fitted to the blade. These sleeves are produced almost exclusively on automatics and capstans, using magazine foods, air chucks, and cemented carbide tools.

The bolsters or inner tubes are in cast iron and it is essential that the material be of good quality to withstand wear. The working life of these varies with the load imposed, and care in lubrication and cleanliness, but ten to fifteen years' running is quite common. The bolsters are produced on autos and specially adapted single purpose machines. These bolsters often have a hole little more than $\frac{1}{4}$ in. diam., $5\frac{1}{2}$ in. long. The collars or bolster carriers are exclusively in cast iron and many different types are called for. These are also produced on autos and specially adapted single purpose machines.

The multiple screw oil cups are also made in cast iron and produced on single purpose machines. The chief interest lies in the quick lead of the screw thread. This is 1 in. lead, 16 start, and is produced on a specially arranged chasing machine. The valuable feature of this type lies in the fact that it is possible to unscrew the cup for refilling from the bottom without having to dismantle the spindle.

It is worthy of note that in the manufacture of these parts, single purpose machines operated by semi-skilled workers are almost entirely used and are difficult to beat by the introduction of the latest and most up-to-date general purpose tools. The manufacture of these parts occupies a factory apart from the ordinary textile machinery production, and it is of interest to learn that the average spindle entails from 70 to 80 individual operations and has a selling value of only 3s. 6d. to 5s. 6d. each.

Time is too short to deal with all the interesting manufacturing details of other parts—which follow the most approved modern machine shop practice.

Foundry.

In textile machinery, cast iron plays an important part and comprises about 75% of the product. As would be expected, the foundry technique has become highly developed during the long period of specialised production. A large amount of work has, however, recently been transferred to modern jolt squeeze moulding machines, and in many other directions newer methods and equipment have resulted in increased output and economies. The main foundries are disposed on three sides of the dressing shop, each foundry originally being served by one or more cupolas of from 2 to 5 tons per hour capacity.

Under this arrangement, there was a considerable duplication of labour, and in view of the reduced demand for textile machinery, the obvious remedy appeared to lie in the direction of closing down a number of cupolas and obtaining the required output from a smaller number having a greater melting capacity. Two new automatically charged cupolas have been installed having a nominal capacity of 8 to 9 tons hourly. Melting is continuous, the metal flowing from the spout (always open) into a self-skimming worm gear operated mixing ladle with a tea pot spout.

Of special interest is the automatic charging apparatus. The hoisting gear is on what would normally be the charging floor. The bucket, in effect a bell hopper containing the charge of either pig and scrap or coke with the requisite flux, is suspended from a jib forming part of a cross moving carriage. Only one cupola is operated at a time, the crane carriage being moved into position

by hand operated mechanism and locked electrically in its correct position.

There are two buckets, one of which rests on a " scale " car. When another charge is needed, one of the loadsmen steps on the car and by means of the electric controller, brings the bucket into a position on the sunken track ready for loading. The car carries a dial which registers the weight of each constituent of the mix charged to the specification and orders of the metallurgical staff. Records are kept of each charge.

The car having now been brought underneath the crane lifting block, one bucket is " dropped " and the second coupled up. The loadsman now steps off the car, presses the hoist button and keeps it pressed until the bucket, moving but yet slowly, is seen to be safe and about 6 ft. from its lowered position. The operator releases the button, when the bucket rises rapidly, finally slowing down and stopping at the charging position. Without further attention, the bucket passes into the charging opening and falls slowly until the flange on the bucket makes contact with the projecting lugs in the cupola, when the bell continues to descend and releases the charge, spreading it about the cupola walls. Still without attention, the bell rises and picks up the bucket, which then descends from the charging level to a position about 6 ft. above the rail car level, where it remains until, by pressure on the " inch " button, it is convenient to lower it on to the " scale " car. By means of a third or emergency button, the bucket can be stopped at any position. By use of this ingenious device, it has been possible to make a reduction in cupola staff of 50%.

The output from these two furnaces, one of which only is operated at a time on alternate days, amounts to 250-300 tons per week. The percentage of coke to melt is 8.7 and of pig to melt 31.3. The blast has a pressure of 10 oz. and a volume of 325,000 cubic feet per minute.

The cupolas are of the drop bottom type and when the day's blow is done, and the last of the slag and molten metal has been drained off, the bottom is dropped and the clinkers released and discharged, passing down a hinged chute into a metal truck previously brought into position. This truck runs on standard gauge rails laid on top of the concrete walls of the " scale " car trench, this car having previously been run out of the way. Clinker discharge ended, the truck is hauled into the yard, the chute end swung back to its clear position, and the " scale " car returned to its loading position for the next day's run.

Another modern addition to the foundry equipment is a rotary barrel sandblast machine which, as compared with the ordinary rotary or reciprocating table type, gives better results with reduced labour.

Output 2 tons per hour.
Continuous action.
Reduced handling.
Slight tumbling effect leaves good edges.
Automatic discharge.
Chilled shot not wasted, cleansed, and returned for further use.

In conjunction with these various improvements, a number of petrol and electric driven trucks have made a tremendous improvement in the material handling problem and, whilst they were at first introduced with some diffidence, they are now an essential part of the foundry equipment. Stillages of various types are used and castings or material moved direct to the machines without any manhandling.

Works Control.

Drawings, planning, processing, jig and tool layouts, time studies, to-day all find a place in the textile engineering works. The old system of manufacturing to sample has gone. Every machine has a works specification or part list made out before manufacture is commenced. Such specifications show every detail down to the last nut and bolt. They involve, in the case of a ring frame, some 800 distinct articles varying in quantity from one to several hundred per frame. The whole of the above-mentioned departments are certralised and all manufacturing details, orders, drawings, etc., issued from this department to the shops.

Many people criticise the quantity of forms and the amount of clerical labour involved in centralised control, without realising the number of people in the works who require information concerning orders and who otherwise must obtain it verbally or by copying and re-copying extracts from the master order.

A master specification of each new machine is issued by the sales technical department to the works office and to the erecting department concerned, the former for the purpose of ordering materials and the latter as a guide to the chief inspector as a means of checking the completed machine against the customer's requirements.

On receiving the master specification in works office, it is scrutinised by a specialist on the partcular machine, who enters on a material specification all the parts required which are not standard stock items.

Newly designed parts are passed to planning section direct from drawing office for routing and an operation layout is pasted on the back of the blue print for the guidance of the foremen. The material specification is duplicated and a copy is passed to everyone who will be concerned with the progress of the orders through the shops. When the standard items, bought goods, etc., are later added, the material specification forms a complete record of all parts which go

to the making of the machine and copies of this full specification are passed to cost department and erecting department. In the case of components made from bar, the required amount of raw material is released from stores by works office who make an allowance to cover set-up scrap, etc.

For each component order a wage card is issued to every room which is called upon to perform work on that component and in the movement of batches from one room to another they are accompanied by delivery notes, a copy of which is posted to central progress section. These wage cards and delivery notes were formerly written out by clerks in the shops, but we have recently installed "Adrema" machines which obviate the necessity for much writing and show a saving of labour, whilst at the same time providing more accurate records.

A description of these machines nay prove of interest. For each component order, or "line" as we call it, a zinc plate is embossed on the "Adrema" embossing machine and forms a master from which any number of impressions may be made in the "Adrema" printing machine, the operator merely feeding the requisite number of cards or forms. In this way are prepared in advance the wage cards and the delivery notes required to carry the work through the shops from start to finish.

The wage cards are filed in the shops until the material comes through from the previous department when in exchange for the delivery note, they are issued to the foreman together with the blue print and any jigs or toools required. On completion of the work the wage card is passed to cost department for computation of wages, etc.

No material is allowed to pass out of the manufacturing department unless released by an inspector and, to ensure this, we allow only inspectors to complete a delivery note. This arrangement would ordinarily impose a heavy load of clerical work upon the inspector, but this is avoided by the method of preparing delivery notes in advance.

For each line of an order, a number of delivery notes are printed on the "Adrema" machine and stapled together in a manilla cover to form a booklet. The delivery note is designed to cut down the amount of writing to a minimum and is also made to serve as an inspector's rejection note. These books of delivery notes serve another purpose, as they are made to form a visual progress record in the shops in the following manner :—

The books are passed from the "Adrema" room to the first department on the route where they are filed in numerical order. On completion of the work in that department, the book is taken from the file and passed to the inspector who extracts a copy for progress section and sends another copy forward in the book with

the materials to the next department. On arrival at the next department, the book of blanks is again filed until the work is completed, when it is passed to the inspector as before. Thus the presence of the book in the file indicates a job in progress and gives a rough visual indication of the volume of work in that department.

In concluding these brief and disjointed remarks, I hope I have convinced you that textile machinery production to-day no longer consists of a factory full of obsolete machinery and untrained, bigoted people devoid of progress or initiative. The firm with which I have the honour to be connected have spent nearly £250,000 in reorganising and re-equipping their factory and are to-day, I venture to suggest, the largest and most modern textile machinery factory in the world.

(*The paper was illustrated by numerous lantern slides*).

Discussion.

Mr. T. Fraser (Chairman) : The manufacture of textile machinery now is not what one usually thinks—a haphazard sort of thing. It is obvious after listening to Mr. King that the procedure is very highly specialised. Mr. King referred to the balance of the spindles and stressed the importance of balance, but what is the effect on the balance of spindles when a mill is driven by an old fashioned lubricated engine as compared with the turbine drive ?

Mr. Eckersley : I am glad that the Chairman stressed the point that the manufacture of textile machinery is a rather different thing from what he expected and understood it to be. I think it will open the eyes of quite a few that textile machinery production is definitely an engineering proposition. In the early part of the paper Mr. King commenced by stressing the economic aspect which forced reorganisation on the textile machinery makers. I think it is a rather remarkable thing that the drop in trade, which was by no means overstressed by the figures shown, should have been so peculiar in its effect on textile machinery production. By that I mean, it demonstrated that textile machinery production in this country depended purely and simply on exports for a large amount of its products, and it was only after the war, when Eastern countries commenced to produce for the Eastern market, that the drop of trade was apparent—and in years to come the same principle might possibly affect other productions in this country. Russia and Japan are manufacturing machine tools now ; in years to come the machine tool industry may be forced to take similar steps. That may seem a rather bold statement to make.

I would stress the fact that even before reorganisation as described by Mr. King took place, I know from personal experience that works' costs were remarkably low. So that further reduction to an international competitive level has been quite a remarkable achievement, obtained principally without new plant. I think everybody in the audience must appreciate the lightness of the sections which have to be handled. The difficulties are rather large as a result of that, because cutting speeds cannot always be increased to any great extent. The job sets the pace, as you will see from some of the samples, and some of the steel spindles are particularly difficult to handle. In conclusion, I must congratulate Mr. King's firm on having made such rapid strides in reducing costs and saving the industry.

Mr. King : Regarding exports, I did not make that quite clear. Up to the end of the pre-war period, the textile machinery trade as distinct from the textile trade, was a monopoly trade. There were

very few firms abroad which in any way competed with Great Britain. But when we were engaged in winning the war, all these other people—America—Japan—built factories during that period and are now our competitors. When we returned to the manufacture of textile machinery, we found that we had to take a back seat. From some of the machinery produced in Japan by our competitors we could have taken any component and fitted it on one of our machines—they had copied our results as far as that! Now that all countries are, so to speak, "taking in their own washing," they no longer buy from us iron, steel, etc.—they look for local sources, and that has a great effect on our trade in this country.

As regards light sections, of course that is a point that particularly strikes one in textile machinery. The bulk of our trade is export, and it must be borne in mind that we have to get these machines transported in places where there are no roads, and the machine must be taken down to the last nut and bolt. You cannot transport this machinery like other classes of machinery, for the reason that there are no facilities for handling, and that is why small thin cast iron sections are used.

MR. CROOKE: I would just like to touch on the fringe of what Mr. Eckersley mentioned, i.e., the question of light sections. When people have a difficult proposition like that, it is nice to know how they get over it in their particular factory. I should like to know how you treat these particular light castings before and possibly after the machine operations. I would like to know some of the difficulties you have to face and the actual scrap you get. Regarding the question of those spindles which have to be so true, what precautions do you take to avoid distortion or remedy distortion? I am very interested to know exactly how you test these particular spindles for running true. With spindles running in cast iron at speeds of 12,000 revolutions per minute, the material must be good or it would not last many minutes.

MR. KING: The question of light sections is certainly one which does not occur so often in any other form of engineering. Cast iron also is not so exclusively used in any other form of engineering with which I am acquainted. Regarding the rails, we make the pattern with a definite camber in it. That camber is obtained by experience. The rails are hammered and stretched to take out any stresses in the material. There are also numerous castings which are annealed. All the spindle parts, and particularly parts not subject to wear, are annealed to obviate stresses.

Regarding scrap allowance, we put what might appear to be an excessive number in the foundry to ensure there be no hold-up in production. The average scrap due to our Foundry and Inspection, and various people, never exceeds 8%. The average is round about 5% scrap from foundry right through to the finished machining.

With reference to the spindles, every spindle is given a running test. The spindles are, of course, checked for truth with dial indicators and they are located in a bearing at the bottom, and rotated against the dial indicator. Apart from that, after assembly, where distortion could take place if the sleeve or pulley is very tight or the casting shows distortion, tests for truth by means of dials are not only again carried out, but it is also finally assembled and put through a test of speed which is somewhere about 10% in excess of its running speed. Any spindle which shows any vibration is returned for reassembly.

MR. PUCKNELL : I would like to ask, firstly, whether any form of payment by results is operated in the textile factory, and what method do you employ for drilling the long holes in the spindle housings ?

MR. KING : Practically all the jobs in the works are done by plain direct piece work. There have been quite a number of piece work bonus systems which had been inherent in the textile trade for many years, none of which was so efficient in the long run as the direct piece rate system. We try as far as possible to fix individual prices for every operation. That has been brought about by the introduction of a piece work ratefixing department who carry out time studies on any new operation, analyse them, and they are then dealt with by a card index system. I am not going to tell you that we have reahed perfection, but we are trying to get things shipshape. All the cards pass through the reatefixing section.

With reference to the drilling of the cast iron bolster, a good deal of that is done with a flat form of drill. We certainly take the bulk of the metal out with a twist drill ; after that it is reamed by a flat drill or reamer. Now that is done in every case by rotating both jobs. In some cases for the reamering, the reamer, of course, is stationary and floating and passes into the bolster of cast iron which is revolving at a very high speed. This operation is mostly done on multi-spindle automatic chucking lathes. Afterwards the bore is checked for truth on a spindle by a dial indicator. The bore must be absolutely concentric. We have found no means of doing it any other way. We have tried other methods, but this still seems to be the most satisfactory.

MR. LESLIE : I am not quite clear as to the method of use of the hydraulic cranes in the foundry. It would appear that modern electric cranes would be much more efficient. In regard to the spindle bearings, would it not be better to have roller or ball bearings for such high-speed spindles ? Referring to the card system, I think this is very excellent in that one can gauge the load, the progress of the job, particularly the load per machine section, but can we take it that the numerical filing also gives you the section, or is it not possible that some jobs will be wanted sooner than others

irrespective of the numeral sections ? How do you control the quota system to get the jobs done in the right order ?

MR. KING : Regarding the hydraulic cranes, I may say that they are forty years old. I have never seen the type anywhere else. It has several advantages. A hydraulic cylinder attached vertically to the wall of the foundry. A lifting beam which moves in a vertical plane is attached to the vertical ram by means of chains passing over pulleys. Some of these cranes are 60 ft. long. The main advantage is that this is all fixed overhead and occupies no floor space, further, that the power cost is very low—there is no delay waiting for the overhead crane as each gang has its own hydraulic crane and operates it as required.

With regard to roller bearings for spindles, there are, as I said in the paper, hundreds of types of spindles, amongst which is the roller bearing spindle, the spindle running directly in contact with the rollers. After years of experience with this type of bearing, it has, on the whole, not proved any advantage at all. You must remember that in the cast iron bearing the point of contact is only somewhere about ¼ in. diam. ; all the rest of the spindle is running in oil. Therefore, only a very small portion is actually bearing, and this portion being a small foot step bearing, friction is almost nil. The machine loading per section of course, is easily ascertained by the number of cards. The sequence is not ascertained from this card but from the material specifications. This specification, which gives the route, is always referred to, and all inspectors and foremen have a copy of the operation layout. The actual sequence of operations within the shop is merely done by the data on the back of the blueprint which gives this sequence of operation.

MR. LESLIE : I don't think you quite get my point. I take it you have a number of parts of similar shape for various customers —individual customers' orders. Is it not possible one will be wanted before the other against the numerical sequence ?

MR. KING : That is arranged for by definite programmes. Every week we give a definite priority list which gives every item on the orders. As far as job orders (by which I mean customers' orders for spare parts) are concerned, these are dealt with by special sections. This part of the works does not use this elaborate system.

MR. F. W. SHAW : How would you account for the fact that America, Japan, and Russia have been able to produce the elaborate textile machinery against our competition, which has the experience of 200 years ? It seems inexplicable to me that they should acquire in a comparatively short time, all the skill and information which is necessary to produce textile machines which can be as good as ours. Is it as good as ours ? If it is not as good, then the Japanese and the Russians and the Americans must be working at a disadvantage as compared with our machinery.

Mr. King: You have touched on a big subject there, Mr. Shaw. My personal opinion is that you have to remember that Japan has got her textile machinery works itemised in certain specialised production. She produces pretty well only one standard class of machine. Japan is only largely concentrating in the East—Japan, China, and that district. They manufacture for one mixture of cotton and are able to produce machinery for that localised market. Japan is now in the position that Lancashire was many years ago, where she was producing machinery for her own use. She had her own market to cope with. We could in the pre-war days produce machinery only to meet our own requirements; to-day we have to try to compete with Japan and other nations. In other words, our home market has developed into a world market where previously it was concentrated in Lancashire. Japanese machinery is definitely in many cases as good as ours, but the whole of Japanese machinery is an exact copy of our machines.

Of course there is the question of labour. This is definitely at a lower grade... But I will say this (it is possibly only a personal view—being in Lancashire I've got to be careful what I say!) Japanese competition will diminish very largely within the next ten years. Japan is not an original country; she has few original ideas. I know from experience that when the young Japanese, who have been in this country and become Westernised, go back to their own country, they are not willing to live on a handful of rice per day. Trade-unionism is becoming a very serious consideration and causes a great deal of internal trouble in Japan. I am also of the opinion that for the last twenty to thirty years the textile machinists in this country have rested on their laurels, but to-day in the modern works there are hundreds of machines being scrapped and replaced by new methods. Production costs are low, and I think our production methods in the textile factories to-day are as good as you will find anywhere else. We are getting back the trade which we formerly lost through lack of push and thinking that we were the only people who could produce machinery. We will never get back to the pre-war days when we were a monopoly trade.

Mr. Shaw (Junr.): I feel that the textile machinery trade was the originator of our methods of production to-day. In the very early days she was using methods that I think our modern motor car works can never attain even to-day, and those simple methods of the past are very difficult to better even to-day with all our modern machinery and our improved methods of organisation. I feel that if our textile production engineers would only turn their minds to producing a motor car instead of a textile machine, we would soon get our £50 car. I would like to know whether the firm with which the speaker is connected use jigs to any extent during the *assembly* of the machine? To what extent is the design of the textile

machine controlled by his customers ?

Mr. King : I feel with Mr. Shaw that mass production actually started in the textile shops. During the war a lot of the movements which were adopted for high-speed production were definitely introduced by the thoughts and experience of textile engineers. To-day in the textile engineering factory we have definitely passed away from that mass production. In this country your markets are spread over the world. We have not to deal only with a local condition for cotton production, but for anybody's needs using any kind of cotton. Every machine has to be so designed to allow for fairly rapid variation to meet those conditions. Therefore to-day we are producing in ones and twos, rather than in hundreds.

Answering the point regarding jigs during assembly, of course jigs are used throughout on the machining side in enormous quantities. The tool room which we have is one of the largest rooms I have seen in a factory of this size. Regarding assembly jigs, we are using more and more every day unit assembly jigs. We are doing as much as is possible to do by means of jig assembly. Regarding control by customers, it is unfortunate that each individual cotton mill depends for its life upon being able to buy in one special market and have a special mixing or blend of cotton whereby one can derive a certain advantage over one's neighbour. That in itself causes a certain definite line to be laid down by the customer when he orders his machine.

Mr. Symes : There is one point on which I should like some further information. You say you spent £250,000 for reorganisation. I should like to know over how long a period. In deciding how such a sum of money should be spent on reorganisation, a certain number of items would be fairly clear and perfectly clearly defined. Others would be most obscure and it would be difficult to visualise requirements. Particularly in workshop layout, it is very difficult to demonstrate in grouping of machines or various other aspects, that sufficient economies will be made to recover the expense in a reasonable time. I suppose a portion of this £250,000 could be quite clearly forecast in its effect on costs, but another portion perhaps could not be clearly defined, and it is this latter spending which calls for considerable faith and courage on the part of the shop management. One case in particular I was interested in was the application of the principle of mechanisation to cupola loading. I was struck with the fact that the installation which must have cost the best part of £10,000 reduced the labour cost to about 10% of the original labour cost. I would like to know the recovery period—how long it took to recover the actual capital expenditure.

According to the local covenants in this district, all prices are to be mutually arranged. This is a most definite clause. I would like to know how many, or what percentage of, prices are accepted

by the machine operators when changed without actual negotiations on the shop floor. Are assembly prices pre-fixed in the same way as machining prices?

MR. KING: The expenditure of the £250,000 covered a period of five years, that is, since the reorganisation period which I mentioned—since the amalgamation of the various firms. I quite agree with you that it is very difficult in many cases to prove to your Board of Directors that when you put up a sum of money that you are able to show a recovery in any time, let alone a limited time; but, of course, the position was rather different because we were faced with the fact that our capacity was very much in excess of our production. It therefore became necessary to retrench, as it were, and confine our activities into a smaller area, which was a comparatively easy thing to lay out. We laid it out to what, to the best of our knowledge and experience, would probably be our limit for the next five or ten years. And that, possibly by good luck as much as anything else, has proved to be pretty well accurate.

With regard to the mechanisation of the cupola loading, the figure Mr. Symes mentioned is practically the right figure. We expect to regain that cost in under three years, primarily due to the number of small units which we previously used, each of which necessitated a gang of cupola loaders and tenters, and so on. You can either have two cupolas doing two tons and a half per hour each, or one doing five tons per hour. The latter means 50% reduction in the number of labourers required to melt five tons per hour. Whilst our cupolas were modern, they were all small capacity. We had numerous difficulties with the present installation although the general scheme as laid out has not been materially altered at all. The difficulties have all been minor ones, and we are still experiencing difficulties. We have been able to cut out all labour with the exception of cupola loaders and one cupola tenter on the front supervising the pouring spout. The cupolas have now been in use for twelve months and maintenance and depreciation on these new cupolas are less than they were on the old ones.

With regard to the fixing of prices, Mr. Symes has hit the nail on the head. It is, of course, extremely difficult to alter prices where in many cases they have been used to certain methods in certain shops for twenty or thirty years. On the whole, I can only say we have had a fair amount of success. Local agreements, of course, we all have to abide by. We try, however, to take the men into our confidence—get them to realise that if they prove obstinate and will not alter, it is likely that they and all of us will be out of work. That method, rather than any hard or fast agreement has proved successful. Assembly prices as far as possible are fixed beforehand, although in the case of certain components such as framing parts where the slight differences between one component

and another are only dimensional, the same price will cover the job. In the case of a new machine entirely, it is essential to pay a lieu rate or work-day rate. As far as ever possible we try to fix prices by time study on the job and by an intimate knowledge of the men concerned.

MODERN INDUSTRIAL LIGHTING.

Paper presented to the Institution, Sheffield Section, by Lawrence M. Tye.

THE connection between good artificial lighting and the profit earning capacity of a factory or works is a matter of hard indisputable fact. In the present age of keen business competition factory owners are realising more and more that success is dependent to a very large extent upon the adoption of up-to-date machinery and methods of production. Such modern methods demand a degree of precision and speed unattainable in the past, and a natural outcome is the need for far better lighting.

The importance of good artificial lighting to the factory owner is made evident in at least three distinct directions :—

Liability to Accidents.—It is found that the liability to accidents, owing to the inability to see objects distinctly increases the sense of apprehension on the part of the worker. Accidents, whether to worker or machinery have now far more reaching consequences than in the past, for they throw out of action essential cogs in the organisation, causing delays and affecting general routine.

Better Production.—Many instances of more rapid and accurate production following improvements in illumination have now been recorded. Experiments conducted by The Industrial Fatigue Research Board have shown that in the cotton and silk weaving industries the output is on the average 8 to 10% more by good daylight, whence it may be inferred that the artificial lighting in such mills is capable of improvement.

Still more striking is the experience of the Illumination Research Committee operating under the Department of Scientific and Industrial Research, which recently reported on the influence of illumination on fine work (typesetting by hand).

It was found that the full efficiency, judged both by output and precision, was only attained with an illumination of 20 to 25 ft. candles, which was considered equivalent to good daylight conditions.

When it is considered that the cost of providing good artificial lighting is an insignificant one compared with other shop charges—frequently not exceeding 1 or 2% of the pay roll, if only a modest increase in output is obtained from good lighting, the results far and away justify the cost involved.

Good Lighting reduces Fatigue and aids General Supervision.

Apart from the beneficial effects of good lighting upon production, and in reducing the risk of accidents, investigation has found that working conditions are materially improved, with the result that there is less fatigue amongst the workers, and in consequence they enjoy better health and more hygienic surroundings. The importance of this side of the question can hardly be over-stated, and very considerable investigation along these lines has now been carried out.

It has, for example, been found that there is everything to be gained from the phsychological aspect in paying more attention to the introduction of light surroundings in the works, which have the practical advantage of avoiding excessive contrasts between light and dark, when the artificial lighting comes into operation. In many instances steelwork and roof trusses have been treated in french grey or blue tones as part of a distinctive and organised decorative scheme. Attention is even now being paid to the desirability of spraying machinery and plant of a colour to give a better reflective co-efficient so that these surfaces no longer present unnecessarily black masses of mechanism, which appear particularly unattractive under schemes of artificial lighting.

It is found that efforts in these directions invite a much closer interest between the management and the workers, and without doubt assist in the search for increased efficiency apart from the assistance it gives to general supervision.

Some of the essentials of Good Lighting.

The avoidance of " glare." Glare results chiefly from unshaded or inadequately shaded light sources located within the field of vision, or from too great a contrast between the brightness of the light source and a dark background of an adjacent surface. To eliminate " glare " arising from the former cause the recommendation is made in the second report of the Departmental Committee on Lighting in Factories and Workshops (1921) that no part of any lamp filament shall be visible when viewed from a point in any direction making an angle exceeding 70° from the downward vertical axis of the reflector—or in the case of localised units, for any person employed at a distance of 6 ft. or less from the source, not greater than 60°. Modern industrial reflector units have accordingly been designed to satisfy these requirements.

Glare arising as the outcome of too great a contrast between the plane and the adjacent surroundings is usually brought about by an irregularly planned lighting lay-out, or in the use of too high a power, light source relative to the mounting height.

Desirable Lighting Intensities.

The requisite illumination intensity (measured in foot-candles*) required for any particular industry will naturally depend upon the nature of the work. For instance, less light is necessary in a shop engaged upon rough work than in a shop devoted to fine and exacting processes.

As an indication of the intensities advocated at the present time, an illumination of 6 to 10 foot-candles is desirable for rough machine work, whilst for fine work intensities of 15 to 20 foot-candles are actually necessary.

Certain manufacturing processes such as engraving, grinding, fine instrument work, etc., even demand intensities greater than these, in which cases it is usually desirable to supplement the usual system of overhead general lighting by additional local bench lights.

Every industrial lighting installation must provide ample illumination on the horizontal plane, and overhead general lighting is usually found to meet these requirements in the most satisfactory and practicable manner. There are, however, many special operations such as borting, gear cutting, rivetting, coachbuilding and erectional work which call for a substantial illumination on vertical surfaces; and these requirements need to be carefully considered when the lighting system is designed.

In calculating a scheme of general overhead lighting it is found that a spacing of 12 ft. centres (144 sq. ft.) using efficient types of industrial reflectors and the present range of sizes of gas-filled lamps meet a very large number of industrial lighting problems. Under these spacing conditions it is possible to meet the requirements for rough work by providing 150 watt lamps (1 watt per sq. ft.) with efficient reflectors to provide an initial illumination intensity of 7.0 foot-candles.

Where the work is of a more exacting character the same centres prove to be very practicable when employed in conjunction with modern industrial reflectors and 200 watt gas-filled lamps (equivalent to 1.4 watts per sq. ft.) to give an additional illumination intensity of 10.0 foot-candles.

For still more intricate work, modern industrial reflector units on the same centres equipped with 300 watt gas-filled lamps (equivalent to 2.0 watts per sq. ft.) will produce an initial illumination intensity of 15.0 foot-candles.

In order to keep shadows to a satisfactory minimum, and also to satisfy the requirement of the machines more or less irrespective of their position, it is desirable that the spacing-height ratio (distance

*The foot-candle is the unit of illumination measurement.

One foot-candle represents the intensity of light received from a source of one candle-power at a distance of one foot.

apart to height) should not exceed $1\frac{1}{2}$ to 1, therefore using Intensive type reflector unites the lighting points on such centres should be 8 ft. above the working plane or 11 ft. from the floor.

There are of course exceptional cases where the ceiling height does not permit of this mounting height being attained. In such cases, having these relative wattage and illumination figures to act as a guide it is a relatively easy matter to close in the spacing by exercising the same desirable spacing-height ratio, and reduce the lamp wattage accordingly.

On the other hand there are a number of industrial buildings where the nature of the plant or the existence of special obstructions such as overhead travelling cranes necessitate considerably greater mounting heights than would be obtained by using this spacing-height ratio.

These problems call for particular care in the choice of an industrial reflector giving the desired light distribution characteristics, and units of a more focusing nature are invariably necessary in order to deliver the major quantity of the light flux on to the working plane and not be unnecessarily lost on side walls and upper structure.

Auxiliary and Local Lighting.

When the arrangement of the factory or workshop is such that the greater part of the area needs only a relatively low intensity, but some special operations require a much higher intensity, the most economical plan is to supplement a moderate amount of overhead lighting with local lights judiciously placed.

Another instance where local lighting may be necessary and even desirable is when work benches are placed around the walls of the workshop. In these circumstances the workers may be standing between the outer row of lighting units and their work.

General Maintenance.

Tests in a number of industrial interiors have shown that the ordinary accumulation of dust and dirt may account for a drop of no less than 30% in the value of the illumination provided. This is a fact which is not always realised, and it is therefore advocated that every works should have a regular and definite system of maintenance to ensure that the lamps and reflectors are at all times kept clean and in proper adjustment.

A further point which is frequently overlooked is the need for maintaining the full normal voltage at the lamp terminals. Seeing that a 1% drop in voltage causes approximately a 4% drop in the candle-power generated, it is vital that in the planning of the wiring system voltage drop should be as far as practicable eliminated.

Semi-Corrected Lighting.

An item of recent lighting interests is the extent to which semi-corrected artificial lighting is now being employed in works and offices to counter the ill-effects upon the acuity of vision in working in a combination of daylight and artificial lighting. This combined lighting difficulty often arises in the case of large working areas unprovided with overhead roof lights so that the centres of the building require to be artificially lighted at an hour considerably earlier than is necessary for the outer portions. There is now ample evidence to show that many workers are aware of an intangible sense of discomfort when working in a mixed light composed partly of weak daylight and partly of yellowish artificial light, and these conditions can be considerably eased by the installation of a semi-corrected lighting system.

Even more exacting conditions are of course met where a true match of daylight is necessary for the successful carrying on of colour work and matching after hours of darkness.

Factory lighting design involves calculations and technical knowledge when all the various factors having an important bearing on the final result are taken into consideration, and therefore it is unwise for those not possessed of expert knowledge on the subject to attempt to plan an industrial lighting scheme without collaboration with the various recognised lighting authorities. Most lighting concerns now maintain expert departments to advise on the correct solution of any specific lighting problem and factory owners would do well to avail themselves of these services in any attempt to make a serious reorganisation of factory or industrial lighting.

Discussion.

Mr. F. Williams (Section President, in the Chair): Well, gentlemen, I think we have had a most interesting lecture by Mr. Tye, and I must say that so far as I am concerned, it is very surprising to see the detailed manner in which this question of lighting has been studied. To most people it always seemed a rule of thumb method as far as they were concerned. It is very pleasing to see that it has been gone into in such a very thorough, scientific manner. There was one point to which the lecturer referred, and that was the question of painting shops, and its effect on lighting. On Friday last, I went to a works that I visit at quite regular intervals, and since my last visit there, they have made a number of alterations. They had painted every one of their machines a light green; they had painted the whole of their stanchions in the same colour, and all above that, their roof principals, the underside of their roof, were painted white, and the whole of the cranes were painted white. It was a most remarkable effect, and I was very much struck with the full lighting it appeared to give to these shops. There is a question I should like to ask Mr. Tye, and that is, whether he would recommend the use of these gaseous discharge lamps in shops. They are being pushed a very great deal, particularly for foundry purposes, by the makers. I am not sure whether any special difficulties are attendant upon the application of these lamps, or whether their use in a foundry has any particular advantage over the ordinary gasfilled electric lamp. At the present time I think most of you will have seen many advertisements by the lamp makers, highly recommending the installation of these lamps.

Mr. Tye: Mr. Chairman, I am very glad to hear your remarks as to an instance where you have seen a works where they are employing a colour scheme, and particularly to note that the upper parts of the shops, and even the cranes, had been whitened, and at this point I would again like to stress how you are helping thereby in getting uniformity of light as well as a higher illuminating efficiency and better psychological effect. On the question of using the gaseous discharge lamp in industry generally we are finding the need to go reasonably slow in its introduction, because there is of course the colour difficulty to contend with as well as the stroboscopic effect of such light which may become of some considerable importance where moving objects are involved. In consideration of the question of colour, we have found instances where the monochromatic effect of either mercury or sodium lighting is disadvantageous to the process, and in other cases where difficulties have been encountered in dealing with various progress cards

printed in colour due to the false colour effects produced. On the other hand, we have found very distinct cases where there is a decided advantage in their use, and on a scheme which Mr. Berry and I dealt with recently, where they were operating on metals such as bright steel, it seemed very forcibly to me that the monochromatic colour of that light was a very much better one for these industries than to work with the comparative yellow composition of the gas-filled electric lamps. Furthermore the light is well-diffused with such mercury sources which is a further advantage under such circumstances. For a foundry I should say that the introduction of gaseous discharge lamps of the mercury type was a sound introduction if the shops were fairly high—say 20 to 30 ft. providing efficient reflectors are used.

Mr. Barber : I should like to ask Mr. Tye whether, in his opinion, a general scheme of lighting could be developed and utilised, which will dispense with individual lamps on machines in a machine shop doing comparatively fine work, where it is the general custom to have individual lamps. The works with which I am identified do that kind of work, and we use, of course, the small electric individual lamps, to which I fitted some time ago, reflectors. The purpose is obvious, to prevent the light shining into the operator's eyes. It gives a concentrated light on the subject. I would also like to ask Mr. Tye, what in his opinion, should be the light intensity for a shop of say about 14 ft. to eaves gutters, and doing comparatively fine work. What is the intensity, and at what point does he measure it ? Does he measure it on the floor, or 4 ft. up ? I am not speaking of any particularly refined work, such as die-setting, but ordinary machine shop work. I would like to ask Mr. Tye something about these photometric light sensitive cells. It is a very interesting thing,and apparently it is operated entirely by the intensity of the light striking a surface, and generating, as he says, a minute current. I should like to say that this is one of the most interesting lectures I have heard, and the question of lighting has, of course, a much more important bearing than anyone has realised until recently. It improves supervision enormously. The whole factory can be seen, and I believe that the figures Mr. Tye gives of output are fully justified by a systematic system of lighting.

Mr. Tye : Replying to your points. Taking the ordinary machine shop, as I mentioned, I feel that a good economic average for spacing the lighting units, using efficient reflectors, is in the region of 12 ft. I think this satisfies all the requirements for general lathe work. I would, however, add that for special processes, boring, etc., I would advise the use of individual lamps, as even under conditions of daylight you meet certain difficulties. In taking the intensity figures in the lecture, we always allow for a working plane of 3 ft. or 3 ft. 6 in. according to conditions, in calculating lighting schemes.

Taking machine shop lighting where they have general lighting on the basis of approximately 12 ft. centres, they do not have local points, excepting for the special processes to which I have referred. In a tool room, as distinct from general production, every machine is best served by a local point in addition to a satisfactory standard of general lighting, say of 8 to 10 foot-candles.

Mr. Simmons : I was very interested in the lecture, but particularly in the question of the colour corrected lamps. Could you give us any figures with regard to the fatigue or increase of output due to the adoption of colour corrected lamps, as against the ordinary gasfilled lamps. I tried the experiment of putting colour corrected lamps in a class room, but they were not liked. The people who had to work in the room objected to the colour. I went to a works once where I saw this type of lighting, and it was pointed out to me that there was less fatigue with the colour corrected lamps than with the ordinary gasfilled.

Mr. Tye : The points which you have raised are very interesting indeed, because they bring up the conditions under which colour corrected light is used. Unfortunately, by the fundamental construction of the spectrum emitted by a gasfilled electric lamp, we have to absorb a quantity of the light to obtain such colour correction. When we go to a works and calculate 10 or even 20 foot-candles for a lighting scheme, and then add a multiplying factor of 100% for the use of corrected lighting, the cost frequently proves to be somewhat prohibitive. That is, I feel, where we have gone rather wrong in practice, because where the intensity with colour corrected light is not sufficiently high, the effect produced is not semi-corrected lighting but more like moonlight. In a factory building you are getting anything like 30 to 50 foot-candles of natural lighting and so it is not logic to try and imitate this with 5.0 to 6.0 foot-candles of colour corrected lighting. I am afraid I am unable to give you any data on a big scale as to the proved advantages to production in using colour corrected light, but without a doubt there are many processes which can benefit by it.

Mr. Harrison : I should like to ask what provision Mr. Tye makes in moving cranes in a workshop, and if at any time stainless steel has been used as a reflector for the lights.

Mr. Tye : I would like to reply to Mr. Harrison by indicating that in the majority of high bay shops where you experience a travelling crane, we purposely stagger the light units, which enables you to avoid shadow. I would prefer to use a larger number of 750 watt or even 500 watt lamps arranged in two rows on such a staggered basis, rather than a single row of higher powered lighting units, because it will cut out the shadow difficulty a good deal. The two rows would cover a 70 ft. or 80 ft. bay much better because you provide better lighting towards the sides. In instances where it

is found that there is localised work under a crane when it is in operation, we have introduced a reflector unit hung on the underside of the crane.

MR. HARRISON: Regarding my point of stainless steel for reflectors?

MR. TYE: Yes, stainless steel has now been used very largely for certain of these instances. I am not going to say that it is better than prismatic glass, as where the latter scores rather heavily is that in the case of a foundry and similar buildings, you have fumes to contend with. The prism reflector is not affected under these conditions. I have heard, and certainly know, quite a number of cases where stainless steel has been used with satisfactory results.

MR. A. LONGLEY: I would like to ask Mr. Tye what advantages or disadvantages he has found with regard to wall lighting as compared with overhead lighting.

MR. TYE: Wall lighting in a high bay, additional to overhead lighting, does help you to deal with vertical sections near the side stanchions, and we frequently advocate its use. The combined installation cost of such an arrangement—although ideal—frequently operates against its use.

MR. MARRIOTT: I was rather interested in your remarks about the gaseous discharge lamps. Suppose you had a shop lit with all that type of lamps, is it not better to work with that than with the gas-filled lamps? I have rather a funny little problem. In one of the shops I deal with, most of it is a machine shop, but smithers also work in the same shop. As soon as it gets dark, the output of these smithers drop. Would it not be better to see things with more of a daylight type of lamp? Are the lamps they are putting up in the streets, which they call "daylight lamps" giving the same effect as gaseous discharge lamps?

MR. TYE: I would say that the outside street lamps and those advocated for works—gaseous discharge lamps—are really the same fundamentally, whether 250 or 400 watt size. In the instance you cite, I think you would also experience advantage in the using of gaseous discharge lamps. Rather peculiarly, I felt that we did score a pull in a certain chromium plating shop where the colour gained seemed to be fundamentally suitable for that process, but although it met the works' requirements very well, it upset supervision very much, because the production cards were changed in colour. The yellows went dark brown, and it rather upset the statistical part of that department.

MR. MARRIOTT: Rather bears out the tale a foreman told me, in a shop lighted with mercury discharge lamps. The lamps were all right to work with, but the light always put him off his supper.

MR. TYE: We had a similar case at a workmen's luncheon at a particular works. The man had rather a varied menu, one course

was tripe and the other banana. The colour of these particular components in the light of the mercury lamp played havoc.

MR. WEEWAY: In listening to Mr. Tye's lecture, I have enjoyed it in every way. There is a question I should like to ask, and that is the comparison of sodium discharge lamps and of mercury vapour lamps. How are the various municipalities taking them?

MR. TYE: That is a very interesting point. Taking it on quantities, there is no doubt that the mercury lamp is running miles ahead, but at the same time, one has to consider all the factors. The mercury lamp had something like two to three years start of the sodium type. There is rather the distinctive difference that the mercury lamp is 250 and 400 watts, which suits large municipal centres for main streets, very well. In the smaller areas, the 50, 70, and 100 watt in sodium are equally attractive lamps, so that where they have been used for the suburban sections, it does rather lead to a tendency to use them when it comes to the highways. Taken on quantities, there is no doubt whatever that the mercury lamp is being sold in larger numbers at the present time. The makers of the sodium lamps are very much less in number than the mercury type.

MR. WEEWAY: It rather struck me that if the mercury vapour type was established, the windscreens would have to be semi-resisting to these lights. I have driven through various districts, and have tried both, and no doubt mercury vapour lamps tend to accidents to motorists.

MR. WILLIAMS: Is not that a question of shielding the lamp itself? I have driven over two lengths of roads which are lit by gaseous lamps. One is very good, and the other one is as bad as it is possible to be. The better one of the two is outside Cardiff, and cyclists and pedestrians can be picked up almost at once.

MR. TYE: There is a very great deal in that, and a good deal also depends on the design of the fittings. Most of the mercury installations are now being made with refracting plate lantern designs, where you get really good light diffusion. There are types where you are getting light similar to a bare lamp, and the consequence is that you have a fairly bright light source to deal with. There is also quite another important factor that comes into this question, and that is the actual road surface, and so I venture to say that though one lighting system may be very satisfactory under one set of conditions, it may be very unsatisfactory under a different set of conditions. These lamps are now usually being supplied something like 28 ft. in height, about 150 ft. apart, using mercury lamps of the 400 watt size, so you have a fairly big volume of light to deal with, and you certainly require maximum diffusion in your fittings, in addition to efficient re-directing properties.

MR. BARBER: With regard to gaseous discharge lamps and the

question of moving machine parts, apart from the prejudice that people have in the colour, is there anything detrimental in the use of them for, say, lathes, using a Widia tool at a high speed ? Is there anything due to the colour, apart from prejudice with people being used to the ordinary light, detrimental to the eye ?

MR. TYE : Of course, for a source such as the gaseous discharge lamp, which is subject to the periodicity of your system, the consequence is that you do experience flicker rather badly. I have not yet had an opportunity to test it out in various works to see if it is sufficiently aggravating in the case of a lathe, to be detrimental. There is no doubt we have to go slow in the introduction of these lamps where movement is involved.

MR. GILFILLAN : When I came to the meeting, I had no intention of staying so long, but the lecture has been so interesting that I had to stay. There were one or two questions I wished to ask, but many of these have been asked by other people. However, this is my experience of lighting in the Sheffield trade. When I came to Sheffield about 3½ years ago, one of the departments in the works was a machine shop, with four bays with a span of 72 ft. This shop was very badly lighted, and the effect on the men was anything but good. We all know the psychological effect that bad lighting has on the workers. However, we had the shop thoroughly cleaned out, all the dust was extracted, and then we started the colour scheme. A cream right from the principals to the wall, and then we put a maroon colour under. We tried that out with good lighting, and the improvement on the workers was so marked that we tested out the effect on the machines themselves. We are now painting the dado wall cream. The end of last year we opened a very small shop. While I was satisfied with the cream, I thought I would try the effect of having a white paint. The difference between a cream and a white is very remarkable. White is undoubtedly superior. In the whole of that shop (I should think there was close on 360 machines) no machine had an individual light. We have travelling cranes up to 150 tons, and we overcome the lighting difficulty by hanging two 150 watt lamps under the cranes. In all the small machine shops, every machine gets its light from the roof. That is my actual experience in the Sheffield trades.

MR. WILLIAMS : Before asking for a vote of thanks, I have an announcement to make, and that is, that Mr. Tye's principals will be very pleased to see any works engineers at a Conference which is being held in London, starting at 10-0 a.m. on Thursday, November 28, at the Holophane Laboratories, at Elverton Street, Vincent Square, London. Papers will be given there covering lighting calculations and developments, etc., and I understand that anyone who likes to attend the conference, can do so as guests of

the Holophane Co.

Mr. Marriott: We have had a very interesting lecture to-night by Mr. Tye. There are a lot of works and shops which would benefit very much by a visit from him. Some of his calculations were very interesting, and very simple, and make us wish he could stop a few hours more. On behalf of the Sheffield Section I wish to thank Mr. Tye for his lecture and slides, and for coming here to-night to give us the benefit of his knowledge.

Mr. Tye: Mr. President, Gentlemen; if I may I would like to express, on behalf of our Company, our very great satisfaction at having been extended this pleasure of meeting you on a common ground, and to be able to give you some indication of what we are doing in lighting development. We are always very pleased to give this information, and I am sure that from our point of view, and mine in particular, I have enjoyed every minute of this stay, and I would like to say how very grateful I am to your President, for the loyal way he has received me, and for the programme he set out in the earlier part of the day. I would also like to thank your Secretary, Mr. Harrison, for the very able and interesting manner in which he has made for me a memorable day in Chesterfield and Sheffield.

THE DEVELOPMENT OF MASS PRODUCTION IN THE GLASS BOTTLE INDUSTRY.

Paper presented to the Institution, Yorkshire Section, by J. F. Shaw, M.I.P.E.

THE oldest record of the manufacture of glass, that can be relied upon with any certainty, comes from Egypt. Beads adorning some of the mummies discovered there are coated with a coloured glaze, which is a true glass, whilst among the tombs of Thebes, pieces of blue glass, similar in composition to the glaze upon the beads, have been found. According to Flinders Petrie, glass-making in ancient Egypt, as distinct from the glaze of pottery, dates back not further than 1600 B.C. and the method then employed was to shape the glass round a core of sand. It was not until many centuries later that ware was made from blown glass. The glass houses of Alexandria were long famed for their ware and Egyptian glass was carried abroad by trading Phœnicians, who probably learned the art of its manufacture from this source.

Rome at one time imported large quantities of glass from Egypt, particularly in the first century B.C. As of course was natural with a country importing a large quantity of a manufactured article, the Romans began to turn their attention to its manufacture themselves, and many Egyptian workmen made their way there and a number of factories were founded. At the time of Nero, A.D.54-68, the manufacture of drinking vessels was carried out.

It was not until about one hundred years later, however, that the industry began to flourish, and then the manufacture of glass assumed such proportions that a principal quarter of the city was given over to the glass makers, and in A.D. 220 Alexander Severns levied a tax on them.

In the thirteenth century the Venetians were famed for their glassware, the industry reaching its greatest heights in the 16th and 17th centuries. It was so important that members of the Corporation of Glassmakers held a privileged position in the state and heavy penalties were imposed on any who went abroad and taught the art to foreigners.

France commenced the manufacture of glass in the fourteenth century, but it was a long time before her products rivalled those of Venice. In 1688, however, Thevart of Paris invented the art of casting glass and was able to produce sheets of a size 84×50in., a

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March 17, 1936.

much larger sheet than had up to this time been produced by blowing.

In England it was not until the year 674 that we had anything to do with the art of the glassmaker. In that year Bede stated that the Abbot Benedict sent for foreign workmen to glaze the windows of the church and monastery of Wearmouth, in Durham, these men were our first instructors in the art. It was not until the reign of Elizabeth, however, that any real development was made, and at this time the manufacture of glass was fostered by the state. At this time also a discovery was made which very soon revolutionised the whole industry, and undermined the pre-eminence of Venice. It was the discovery of lead flint glass, stated to have been first made in London in 1537 at Savoy House in the Strand. Covered pots for melting glass were also an English invention. In 1635 pit coal began to replace wood for the firing of furnaces. A great deal of credit must be given to the second Duke of Buckingham for the improvement in English products. He brought Venetian artists to London for the manufacture of drinking ware and sheet glass. In 1696 Houghton gave a list of the glass houses in England and Wales, from which it appears there were about ninety, thirty-eight making bottles.

The chief ingredients in the manufacture of glass are—alkali, lime, and silica. At the close of the eighteenth century two methods of obtaining alkali were in use. One method was to burn wood, the ashes lixiviated with water and re-crystallisation, a crude potash, was obtained. The other method was to use the ash of seaweed, also purified by lixiviation and consisting chiefly of soda (sodium carbonate).

Of other material used one hundred years ago, sand and limestone or chalk, are still used, the only change being the use of purer materials, particularly in the elimination of iron, the result being a glass of better colour. The use of ground flints as a source of silica has long been discontinued, and " flint glass " is no longer denoted because of the origin of its silica.

Up to the year 1872 glass was universally melted in pots, and to-day for some glasses this method is still in use, the factory with which I am connected still melt for some classes of bottle by this method.

In the early furnace the pots were set in the furnace and directly heated by a centrally placed fire, burning wood as a fuel. By about 1850 coal had largely replaced wood.

The next furnace to make its appearance was the direct fired furnace. The furnace was built of refractory material in which were placed the pots. The fuel burns on the grate, the flames from which surround the pots, the products of combustion passing out of the furnace chamber through small flues into the chimney

and so to the atmosphere. In a furnace of this type, constant attention must be given to the fire as the greatest possible heat must be attained in the furnace, a temperature of 1300° to 1350°C. being required round the pots. It will be readily understood that in a furnace of this description the efficiency is very low, the flames passing into the flues at a temperature very little below that at which they entered the furnace and so a great amount of heat is lost. Inattention to the fires on the part of the furnace man, with the resultant variation in temperature would result in disaster to the pots, causing cracking and breaking, and allowing the molten glass to run over the " siege," as the bottom of the furnace is called, and on to the fires.

In a furnace of this type three to seven tons of coal are required to melt one ton of glass, this fact alone being sufficient to condemn any furnace at the present time, although I myself can well remember furnaces of this type being used in Leeds.

Mention has been made several times of the pot in which the glass is melted. This is made of fireclay, entirely by hand and by a very careful, slow and lengthy process, which I do not propose to deal with to-night. It will be sufficient to say that the old potmaker was a very respected member of any glass factory, as faulty potmaking could be a source of great loss. Before a pot can be put into a furnace it is necessary to heat it up as near the furnace temperature as possible, this is done by means of the " pot arch." The pot is placed in the pot arch and very slowly heated for a number of days, the pot being gradually brought up to temperature and then set in the furnace.

The next step in furnace design was the introduction of the semi-direct fired furnace. In this type of furnace, use is made of secondary air for the burning of the gases coming from the fuel bed. The coal is burnt in the firebox, the products of incomplete combustion pass through the "eye," here they are met by the secondary air which passes through the channels round the firebox,the burnt gases pass through the flues and then to the chimney. This type of furnace was a distinct advance on the direct-fired furnace, one ton of glass being melted for the expenditure of two tons of coal. It will be noticed that the floor of the furnace slopes upwards towards the " eye " so that in the event of pot breakage the glass cannot get on to the fire. A defect of this furnace was that, unless there was a strong chimney draft, there was a positive pressure in the furnace and so secondary air was prevented from entering, causing incomplete combustion. In cases where this happened, the secondary air was blown into the furnace by means of a blower.

In the year 1860 a great revolution in furnace design followed the introduction by the brothers Siemens of the heating of a furnace

by means of producer gas, and the regenerative pre-heating of gas and air.

It was not until 1872 that the greatest advance in furnace design was made, and without which the fully automatic bottle machine would be an impossibility. That was the introduction by F. Siemens of the regenerative " tank furnace."

In the continuous tank furnace there is a melting and working zone. The raw materials are introduced into the furnace through a " dog house." This is a box-shaped projection at the end of the melting zone. The raw material is shovelled into the dog house and is pushed at intervals into the furnace, through a hole below the level of the raw material. Charging by this method prevents the entry of cold air into the furnace, the raw materials are also hot when pushed in. They are also better distributed over the surface of the glass in the melting zone. It will be seen therefore, that an even temperature is more easily kept. The gas flames sweep across the furnace and melt the raw materials, the furnace temperature at this point being between 1350° and 1400°C.

As the workmen or machines draw the glass out of the working zone, the glass in the melting zone is drawn towards it. Now as both workmen and machines draw the glass from the surface, it will be readily seen that there is a tendency for the partly melted raw materials and also any impurities floating on the surface to be drawn to and into the working zone, resulting in " bad metal." To prevent this, a bridge is built across the end of the melting zone to above the glass level. A hole, known as the dog hole, is left, through which the glass can pass from the melting to the working zone. The " dog hole " is usually about 12 in. square and is on or slightly above the furnace floor level. The working zone of the furnace is usually semi-circular in shape. As it is necessary that the temperature of the working zone should be less than that in the melting zone, glass at 1400°C. being too hot to work, some system of checker work is usually built on the bridge, to bring the temperature in the working zone down to about 1250°C.

During recent years many furnaces of the recuperative type have come into use. Recuperative heating is continuous, requiring no reversal and one set of chambers only.

Recuperative troubles are lack of conductivity of heat through tubes—tendency to crack and allow air and waste gas to mix. Oil fired furnaces are much simpler to construct—easy to control—but very expensive.

With the development of the melting furnace there came also the development of the gas producer. Three forms of producer gas are in common use to-day.

(1) Air-gas or simple producer gas, obtained by passing air

through the mass of incondescent coal or coke.

(2) Water-gas, produced by passing steam through the incondescent fuel.

(3) Mixed producer gas, obtained by the use of steam and air simultaneously. It is the mixed producer gas that is commonly known as " Producer Gas."

The Siemens Producer is an air gas producer, consisting of a rectangular chamber with an inclined front. There is a grate at the bottom of this inclined front. The fuel is fed in, falling in a thick bed upon the grate. By chimney draught the necessary air for combustion is drawn through the grate, the gases then formed pass out of the producer.

Air-steam gas is the gas most commonly used for furnace work. The Duff producer is a producer for this gas. It consists of a chamber which can be either square, rectangular or cylindrical. Running across the producer at the bottom is a V grate through which the air and steam are blown. The fuel is charged in intermittently and the ashes, which slip off the inclined grate, are removed periodically from the water trough, which seals the producer bottom. Poker holes are provided in the top, the settling of the fuel being assisted by poking. This type of producer is in common use to-day.

From the static " mixed gas " producer we get the mechanical grate producer and then the mechanical producer. The Morgan gas machine is a producer of the latter type. The makers of this producer deny that any agitation of the fuel bed is necessary, and say that " if the coal is properly spread and the furnace continually levelled, all that the fire needs is to be left alone." Other disturbance causes variation of density which create hot places and consequently poor gas and clinkers.

In this producer there is a continuous coal feed on the fuel bed and as the whole machine revolves, the leveller bar keeps the surface of the bed level. The leveller bar floats and it can therefore take care of any variation in height of the bed.

The blast is delivered from three hollow radial arms which connect with a hollow ring going round the whole circumference of the producer. A steady pressure is therefore distributed in the fuel bed. The producer is water sealed and a plough is provided for the removal of the ash. The whole of the revolving parts are supported on three large rollers. A producer of this type is capable of gasifying 3,000 lb. of coal per hour.

After a bottle is made it must be annealed. The reason for this is that glass cools at a very rapid rate and, as the outside will cool quicker than the inside, strain is set up and fracture will result. To obviate this the bottle must be slowly and evenly cooled. This is is done either by means of the " kiln " or the " lehr." The kiln consists of a brick chamber at the front of which is a door of sufficient

size for the convenient introduction of the glass ware. In the roof of the kiln a dampered chimney is provided. There is a coal or coke fire near the door. As the bottles are made they are placed in the kiln one on top of the other until it is full. The kiln is then sealed and allowed to cool. It will be seen that this method of annealing is a slow and uneconomical process and for mass production is useless, as it takes three days to anneal a bottle. The method used to-day is by means of the continuous annealing furnace or " lehr."

The lehr consists of a tunnel varying usually between 80 and 90 ft. long, through the tunnel passes and endless belt. The front end of the lehr is heated, sometimes by coke fire, but usually by gas. The products of combustion are allowed to pass down the tunnel to a chimney placed down the lehr, approximately three quarters of its length. By this means a gradual falling temperature is obtained down the tunnel. The articles to be annealed are placed on the belt, which slowly moves through the tunnel and so are gradually cooled, the process taking about three to four hours.

Now, a bottle, immediately it comes from the machine as the finished article, contains more heat than is necessary for its own annealing. This led to the introduction, in recent years, of the so-called " heatless lehr." The function of this lehr is simply to utilise the heat in the bottle for its own annealing, this effecting a great saving in fuel.

It consists of a long tunnel, as in the case of an ordinary lehr. The belt is known as a mattress belt, similar in appearance to a spring mattress. The sides of the lehr are heavily insulated, asbestos being used. To maintain a proper temperature drop, the heat can be drawn off at various points down the lehr. A fuel oil burner is provided at the front, to heat up the lehr to annealing temperature should it have been stopped for any reason. It is also used when small bottles are being made, as they lose their heat very quickly. The time taken to anneal in this lehr is about two hours.

We have now dealt with the development of the essential plant necessary for the manufacture of glass, without which, the mass production methods in use to-day for the production of bottles would be impossible. We will now follow the actual manufacture of a bottle from its beginning.

The chief ingredients of glass are : silica, soda, and lime. I do not propose to deal at all with the chemistry of glass, that is a question for my friends at Sheffield University. A batch for the manufacture of glass, very suitable for white bottles is :—

Sand	1000	parts.
Alkali	375	,,
Limespar	220	,,
Felspar	37	,,

Borax	...	...	...	10 parts
Arsenic	...	...	...	$2\frac{1}{2}$,,
Decolouriser		...	...	9 oz.

The ingredients are carefully weighed and mixed in a mixer of the concrete type. The batch is then filled into the furnace and melted.

In the old "Flint-Hand" process the men work in sets of three men and a boy, called a "chair." There are two "blowers," "maker" and a "taker-in."

The blower gathers the molten glass on the end of a mild steel pipe, which is usually about 5 ft. long and $\frac{3}{4}$ in. thick, with a $\frac{1}{4}$ in. hole. He does this by allowing the pipe nose to touch the surface of the glass, and then by twisting the tube gather the glass on the end. He immediately takes it and shapes it on a "marver.", making and blowing the "parison," after which he transfers it to the mould and by mouth blows it up into shape. He then takes the blow pipe with the adhering bottle and with the aid of a pair of dull shears cuts a groove in the neck of the bottle just below the blow pipe. A slight tap on the pipe end and the bottle breaks away at the sheared mark.

The bottle is then taken up by the maker in what is known as a punty, and the neck re-heated in a small by-furnace or "glory-hole." When it reaches the desired temperature, the maker then finishes off the neck. He does this by rolling the punty containing the bottle up and down the chair arms and by means of tools or dies, shapes the ring. The bottle is then taken by the boy on the end of a long iron rod and placed in the lehr to anneal.

It occurred to Ashley of Castleford, that a lot of the work done in making a bottle by hand could be done by mechanical means, he therefore introduced the "parison" or blank mould which is equivalent in its action to the marvering and blowing of the glass. He also introduced the use of compressed air for the blowing of the bottle. These ideas form the basis of all bottle machines of the present time, that is (1) the shaping of the parison or blank, (2) the blowing up in the finishing mould.

Improvements were rapidly made on the early Ashley machine of which the Schiller is one, many machines of this type are in use to-day, being very suitable for some classes of ware (small light bottles).

From the stationary machine of the Schiller type, the semi-automatic or hand-operated machine made its appearance. This was quickly followed by the fully automatic machine of which the Lynch and O'Niel are the most widely used to-day.

With the introduction of the fully automatic machine it became necessary that automatic methods should be employed to feed it.

The first feeders to be used were of the flow type. Next came the feeders employing a plunger to assist in the function of the " gob " of which the Miller was one of the first.

Now, in designing a feeder the first thing that must be remembered is, that a given amount of liquid will flow through a given orifice, in a given time, at a given temperature. In glass feeders the only thing that can vary is the temperature. In a miller feeder if this occurs the weight of the glass delivered will vary. This can be regulated to some extent, by varying the height of the plunger, with respect to the orifice, but at the expense of the shape of the " gob." Keeping this fact in mind Rankin patented his feeder, and a very successful machine it has proved to be.

This particular feeder in turn had its faults and has been superseded by one of improved design, which we are working to-day. The bottle machines so far considered have been " feeder fed machines." There is another method of making bottles, by automatic method, and that is by a process patented by Owen early in the present century, known as the vacuum or Owen process. The machine used for this process is a continuous rotary machine and is electrically driven—6 h.p. It consists of a number of " arms," " heads," or " units," as they are called, located radially around a central column, the column being mounted on a travelling bed. Each " head " is a complete bottle making unit, and carries its own blow mould, parison mould, neck rings, and plunger. The mechanical movements of each head being actuated by stationery cam paths fixed to the central column of the machine. The machine operates in conjunction with a " revolving pot."

This is composed of a combustion chamber over a revolving shaped pot. A portion of the pot, about 16 to 18 in. is left exposed beyond the walls of the combustion chamber. The parison moulds of the machine dip into the exposed section of the glass, consecutively, as the machine revolves. As they touch the glass a vacuum is created in the mould and the glass is sucked up into it, forming the parison.

As the parison mould rises away from the glass a knife cuts off the tail of glass. As the machine rotates the parison mould opens, leaving the glass parison suspended in the ring mould. The blow mould then rises and closes round it. Compressed air is then admitted and the parison is blown up to the finished bottle. At a later stage the bottle is ejected from the machine.

It will be realised that to keep a machine of this type working continually, very large orders must be obtained, it being very uneconomical when dealing with small orders. There was, then, a need for a unit capable of dealing with the smaller order. To meet this need, perhaps the most successful is the " Monish " machine.

This machine was originally designed for the small factory

catering for buyers who are unable to purchase in large quantities at one time. The patents covering the suction principle having expired, it was decided to adopt this principle instead of a machine operating by means of the flowing device, it being possible, using the suction principle, to produce bottles of exact capacity and weight, and at the same time, of a superior appearance. So successful is this and similar small machines, that I am inclined to believe that a furnace installed with four or five of these machines will prove to be more economical in the long run in bottle production than can be obtained from large units.

In conclusion, it will perhps be of interest to compare the production of the different methods of manufacture. Considering a bottle of 8 oz. weight :—

By hand—in seven hours—1,400 bottles (three men and one boy).

By Schiller machine—in seven hours—2,000 bottles (three men and one boy).

By Schiller machine—in seven hours—Duplex 5,000 1 oz. Pomade.

By automatic machine, Lynch A—in seven hours—8,400 bottles (20 per minute) (one man and two boys).

By automatic machine, Lynch 10—in seven hours—12,600 bottles (30 per minute).

By Owen Suction, 6 arm—seven hours—8,400 bottles.

By Owen Suction, 10 arm—seven hours—14,700 bottles.

By Owen Suction, 15 arm—seven hours—21,000 bottles.

For certain kinds of bottles, a much bigger production than this can be obtained on a suction machine. This is done by the plural mould operation. This is where there are three bottles made at one time in each head. There is an actual case of a bottle of a $\frac{1}{2}$ oz. capacity being made, three in each mould, on a 10 arm machine. The machine revolved at 6 r.p.m. and over a period of seven days produced an average of 10,080 good bottles per hour, or 1,680 gross per day.

(The paper was illustrated by numerous lantern slides.)

Discussion.

COLONEL BRAY (Section President): When I introduced Mr. Shaw to you I told you it would be a fascinating paper and I think you will agree with me that that is a fact. We are much indebted to Mr. Shaw for the tremendous amount of work which he has put into this paper, and also for the beautiful and extraordinary pictures with which it has been illustrated.

A VISITOR: I would like to ask Mr. Shaw how they get that little ball into the top of a lemonade bottle.

MR. SHAW: That is done by hand. That type of bottle is known as a codd bottle. It is made by what we call the "bottle house process," it is not a method we use in the flint house. The bottle is made, as I have told you, by hand working; the neck is the last thing to be made. The bottle neck is put into a bi-furnace and reheated, the man has a marble which he puts into the bottle and then makes the neck.

MR. R. J. MITCHELL: I should like to ask a few questions, firstly in regard to the heating of glass. Electricity is becoming, one might say, fashionable as a heating agent in furnace work nowadays, and I wondered if some type of electric arc furnace might be applicable; in spite of the heavy cost of energy I would expect certain technical problems inherent to glass melting could be overcome. There might be some advantage in eliminating dust, for example. One always admires the translucent purity of even a glass bottle which strikes one as little short of amazing when you examine a reasonably well made machine-made bottle; there are so few signs of any imperfections.

Another question that occurs to me is that one would expect that, taking into account the beautiful finish of the outside surface of a bottle, as a rule there would be some sign of the texture of the mould's surface. Broadly speaking, that is not discernible on many bottles. I refer to the bottles the chemists sell containing expensive materials—perhaps I should say high priced, not expensive!

Another point which occurs to me is whether, apart from the metallurgical problem associated with the moulds themselves, chromium plating has been found advantageous in respect of maintaining their surface quality.

I should also like to know what material is used for the plunger in the type of feeder where a plunger is employed, and also whether in the orifice any problems are encountered in regard to very severe corrosion at high temperatures. The plunger and die must have a

terrible life with that hot material flowing through under such conditions.

Mr. Shaw: With regard to the heating of glass by electricity, I think that it is quite out of the question on account of the cost. We use on our present furnace 100 tons of coal per week. It is a 200 tons furnace, drawing varying qualities from about 140 to 200 tons per week for the expenditure of 100 tons of coal which we make into gas ourselves. We could not even think of using anything in the nature of town's gas. Even with coke-oven gas with firms that are well placed for the use of that I doubt very much if they can use it as cheaply as producer gas. We have got to get down to a very low figure.

Mr. Mitchell: Have you worked out what a 100,000 B.T.U.'s is, or, say, a million?

Mr. Shaw: I am afraid I have not.

Mr. Mitchell: Do you use a very high grade of coal?

Mr. Shaw: Yes, Glass Houghton coal, it is very low in ash, somewhere about 4%, the percentage of the other things in the coal I cannot just tell you from memory. I will have that ready for you on Friday.

With regard to the texture of the mould, the mould has to be very hot when the glass drops into it. When we start up on Sunday night we go on for half to three quarters of an hour before we get the moulds up to temperature. They have got to be glowing red (Mr. Mitchell: 600°C.?) Round about the necks of the bottles about 600°C., and it must be well up to 700 to 800° in the base. The base of the bottle is much hotter than the neck owing to the fact that the neck is the first thing to be made. The description of glass is sometimes given as that of a super-cooled liquid. It cools very quickly, as a matter of fact we reckon about a minute from the molten state to its being sufficiently hard and set that we dare do anything with it, that is as it comes off the machine. I suppose you are referring to chromium plating on the surface of the mould? (Mr. Mitchell: Yes.) I don't know what would happen to them at that temperature.

Mr. Mitchell: In the technical press I have seen references to chromium plating being applied, but if it has not been applied in your works I doubt whether it is practicable.

Mr. Shaw: The moulds do not last a long time. The glass plays havoc with the mould joints, much to the joy of the mould maker. They cost £100 per set, and we are continually repairing them from the moment we put them on. We cannot afford to experiment with the mould itself.

Mr. Mitchell: Do you get a very good mould surface?

Mr. Shaw: Yes, by careful polishing. It has been suggested we use different kinds of steel and different kinds of metal for making

moulds, but I do not know of anybody who uses anything but cast iron. We do not make our own moulds, we get them made out—it is a specialist's job.

With regard to material for the plunger. You have struck on a very sore point. That brings back very bitter memories of the old days of fifteen years ago. We then used ordinary fireclay. We put them in the feeder as near to temperature as we could. They immediately broke and many times we have had to put in four, five, and six before we could get one to stand up. Now the Morgan Crucible Company supply nearly all plungers for glass feeders. What the composition of the material is I don't know, nor will they tell you. It has a lot of "Siliminite" in. We can with a Morgan clay plunger take it cold, put it straight into the feeder, and within ten minutes start working. We have very little trouble. The orifice bushing is made of the same material.

As far as corrosion is concerned, they never have time to corrode. We are always changing the moulds and the bushes. If they are in use a week they begin to corrode, but with the control of a sleeve or in our case, a valve, any slight increase in the orifice bushing we can take care of with the valve or sleeve, but as I say we don't usually have them in use long enough. The trouble is that consumers don't place big orders with one firm. They place orders with three or four firms and have a few strings to their bow. The orifice bushing has never time to corrode. We make up to 100 gross in eight hours; this was done on a machine working last week. Say we get an order for 5,000 gross to be taken over a period of say twelve months. We put this mould on the machine. We are making 100 gross in eight hours, 300 gross per day, 900 gross in three days. If we were to run the whole 5,000 gross we should have to put them into stock and there would be the cost of handling. We don't do it. We make a fair quantity, as many as we can stock conveniently.

Mr. Fishburn: Can bottles with an internal screw in the neck be made on an automatic machine or must they be hand blown? Another point, can Mr. Shaw verify the talk as to whether the old theory of coloured glass is lost? Is it true that we cannot make it to-day?

Mr. Shaw: With regard to the internal screw in the neck. My grandfather claimed to be the first man to do it. Whether it is true or not I don't know. The internal screw is formed by the pressure of air behind it or the suction by the vacuum and then in the withdrawing of the plug, it is withdrawn and revolved at the same pitch as that of the screw. Internal screws are made by both hand means and automatic machines.

With regard to the formulae for coloured glass, that is a matter of chemistry. I do not know a great deal about it. It does seem

to be a fact that we cannot make glasses to last as they did in the olden days, but I shall have to enquire from my colleague down at the works and ask him what he thinks about it. Glass for windows and plate glass are entirely different trades from glass bottles.

MR. A. SYKES : We have had a paper to-night which I think to most of us deals with a rather novel subject somewhat outside ordinary engineering. We are greatly indebted to Mr. Shaw for his disclosure of intimate details of manufacture. In listening to a paper of this kind one is reminded of the immense range of the mechanical arts. I am quite sure to look at some of those complicated machines makes one's head ache. Mr. Shaw showed us various kinds of furnaces and I noticed illustrated Siemens regenerative type of furnace. I noticed that it contained many of the constructional features of the general types of steel furnace, also by Siemens. Has the steel industry contributed something to the glass bottle industry ? There is no doubt one has benefitted by the other.

I have been wondering why it was necessary that the furnace should contain such a huge quantity of glass, I believe Mr. Shaw said 200 tons. It is also interesting to note the reversion from the complicated type of machine to the simpler one. Is that a case where the capital cost has begun to outweigh the saving in labour costs ? I realise that some of these complicated machines can only be used where large quantities are required. It is amazing to see the very low price at which glass bottles can be obtained at the present day.

MR. SHAW : With regard to the regenerative furnace that we use in the glass industry. I think Siemens introduced his furnace into the steel trade before the glass trade, because you have no doubt seen that the glass furnace and the steel furnace are practically the same. I believe Siemens introduced his furnace actually to the steel industry. There is a fable that the tank furnace came into being through the breaking of pots, but I don't think any truth can be attached to it. I think Siemens did actually introduce his furnace to the steel trade before the glass trade.

With regard to the question as to why the furnace contains such a big weight of glass. In the old days we reckoned 12 sq. ft. of furnace area for 1 ton of glass per day, but we have got that to-day to somewhere in the region of 8 sq. ft., but we work better in the region of 1 ton per 10 sq. ft. per day. You will quite see that when we are pulling a lot of machines on the front there is a big weight in the furnace gradually going through the melting process, there is a refining process going on. We do work furnaces with small weights and small units on the furnace.

With regard to the use of the big machine and coming back to the smaller machine, that is a fact to-day. The machines were developed to such an extent that we went up to the 15 arm machine using

plural moulds or dual moulds. The result was that the quantities produced were enormous and we could not get orders to keep the machines going. I know one firm within 20 miles of here who have stopped a big "Owen" machine and introduced "Monish" machines. They are far more flexible, they give you a bigger range of product. You could make a different type of bottle on every head. I don't mean you could make a 1 oz. phial and a whisky quart bottle on adjoining heads at the same time. They would require different temperatures, of course. You can make different bottles on different heads if working at about the same weight, say on the suction principle. As I said, on the big machines if anything goes wrong, such as changing a mould, for instance, you have to stop the whole machine until the mould is changed. It is not so with the smaller units where you have say three heads against the 15 heads of the bigger machines, and also there are far more orders to be got that can be taken care of with the small unit than the big one. The smaller machines are far more economical. Whereas the "Monish" machine costs about £1,700, including fore hearth, the big "Owen" machine, I am not quite sure, and will not commit myself on the figure, but I should say it is well into five figures, round about the £30,000 mark. There is a very big difference between £30,000 and £1,700.